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THE PROBLEM OF CROP PRODUCTION

BY
PROFESSOR JOHN BRACKEN

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MINISTER OF AGRICULTURE

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TRANSMISSAL.

HON. W. R. MOTHERWELL,
Minister of Agriculture.

DEAR SIR,—In the accompanying manuscript Professor John Bracken deals very fully, very clearly and very entertainingly with the large and important problem of crop production. This contribution by Professor Bracken is very timely. Much thought has been given to methods of increasing production, but the profitableness or otherwise of those methods has not been so carefully studied. Unfortunately, therefore, sufficient data is not available on many phases of this question to afford conclusive proof regarding the relative profits from various methods and practices which are necessary owing to the varied conditions found in different districts in Saskatchewan. A great deal of valuable information is available, but much more experimental work will have to be done before the problems considered in this excellent bulletin can be determined. The reading by studious agriculturists of this manuscript, which I recommend for publication, will, I feel sure, by a closer study of "The Problem of Crop Production," bring us nearer to a solution of many phases of the problem than we are at present.

F. H. AULD,
Deputy Minister of Agriculture.

DEPARTMENT OF AGRICULTURE,
REGINA, *May 5, 1917.*

The Problem of Crop Production

The Factors of Crop Growth, Profitable Production and Agricultural Permanence

By **JOHN BRACKEN**, Professor of Field Husbandry,
University of Saskatchewan

The control of crop yields and the maintenance of soil productiveness are problems that directly affect the prosperity of both the individual and the state.

An increase in net return equal in value to one bushel of wheat per acre on the land at present under cultivation in Western Canada would, at 80 cents per bushel, pay the whole cost of the general expenditure for purposes of government of the three prairie provinces.

The same increase per acre per year for ten years would pay off the present provincial debt of Manitoba, Saskatchewan and Alberta, and still leave $80,000,000 to use for other purposes. It would pay off the total mortgage indebtedness of every farmer in Western Canada.

An increase in net return equal to one bushel per acre would mean that approximately $15,000,000 additional cash would be made available for that section of the community engaged in supplying the needs of the farmer and in distributing his products—the commercial and industrial interests; while a decrease of one bushel per acre would mean that an equally large amount of mortgages, loans and notes would remain unpaid for at least an additional year.

THE PROBLEM IN A NUTSHELL.

If one bushel per acre or more of an increase is to be obtained, or even if one bushel or more of a decrease is to be prevented, the men who control our greatest resource, viz., the soil, must know

(1) **The factors that are essential for the growth of crops.**

(2) **The factors that affect the profitable production of crops.**

(3) **The factors that affect the permanence of a profitable agriculture, and**

(4) **They must not only know, but they must put into practice the means at their disposal for controlling or influencing the factors of growth, profit and permanence.**

A statement and brief discussion of the fundamental principles underlying crop production, has seemed to us essential to a proper appreciation of the subject, both by the producer and the student of agricultural affairs. In this article we have, therefore, endeavoured to bring together the various phases of the question in such a way that the reader may get a general view, even though a brief one, of the relationship of the different parts to each other and to the problem as a whole. No attempt has been made to discuss the art of farming—that has been and will continue to be discussed in other places.

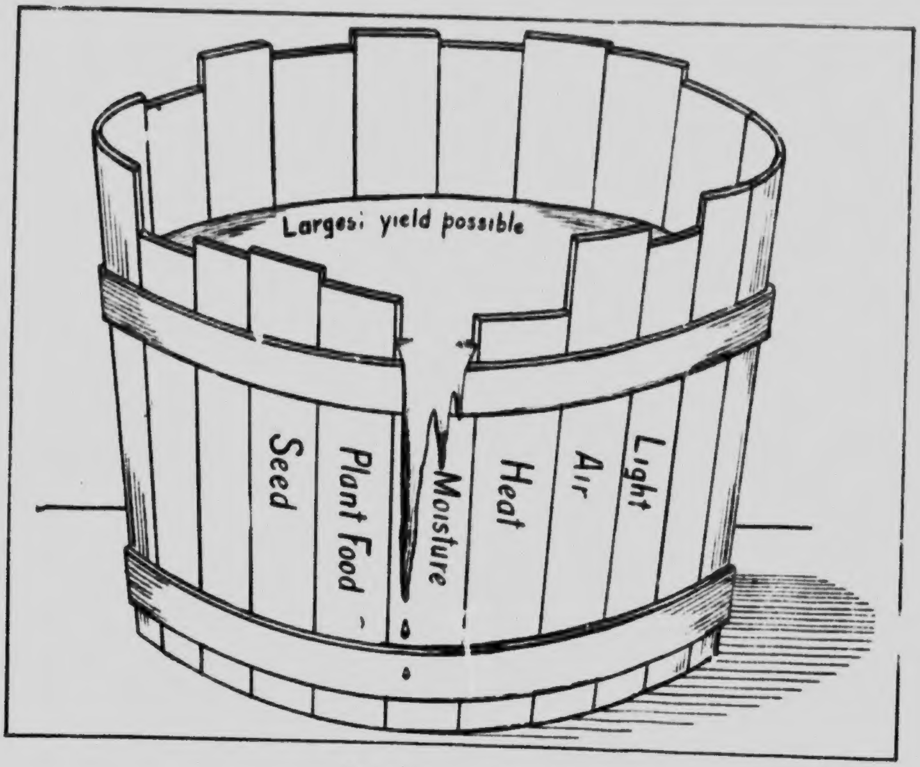
The First Part of the Problem—That of Growing Crops

The factors that must be provided before plants can grow are:

1. The seed—which contains the life principle; the reproductive part.

2. Plant food—the chemical elements of soil, water and air that are available to plants and that are necessary for growth.

3. Water—a plant food itself and also a carrier of plant food from the soil to the plant.



Soil Fertility Barrel.
Drawing from Dovenock's idea of illustrating the principal of "limiting factors" in soil fertility.

4. Heat—without which the life processes of the plant—germination and growth—cannot go on.

5. Light—for the synthesis or building up of organic tissue from the inorganic elements of plant food.

6. Air—which not only supplies a large part of the food of plants, but which in small quantity in the soil provides a desirable environment for plant roots and at the same time plays a large part in the development of "available" plant food.

Fortunately for us nature provides most of these requirements with a lavish hand. It remains for man to increase, or at least maintain the supply of those that under his own climatic and soil conditions have been either wasted or but sparingly supplied.

LIGHT AND AIR ESSENTIAL, BUT OF LITTLE PRACTICAL IMPORTANCE.

Light and air are as important to the plant as plant food, water or heat, yet neither is as important to the crop grower for the reason that he finds both provided in very great abundance. More light than reaches the earth in most climates where agriculture is practiced, is seldom needed, and even if it were, the amount could not be increased profitably.

Nature supplies plenty of air above ground and in all except humid climates, low lying soils, or very heavy lands sufficient in the soil as well. It is our business only to regulate the supply so that the soil will contain neither too much nor too little, but just the right amount for good tilth.

FROST THE LIMITING FACTOR IN NORTHERN CLIMATES.

The average number of days between spring and fall frosts, for a period of ten years in Saskatchewan, varies from 73 in the north-east to 133 in the south-west. The shortest period between frosts during the same length of time was 33 days for the north-east and 101 for the south-west, while the longest frost free period in each of these districts was 112 and 163 days respectively. These figures probably represent the extremes in length of frost free period for most of the present settled area of Western Canada.

It is apparent from these data as well as from actual experience that in northern climates nature sometimes fails to provide enough heat to mature crops, without injury from low temperature, and that, therefore, man must either add to the supply or take such steps as will offset the danger from "frost." This is one of the two chief difficulties facing the crop grower in Western Canada. There is need for developing a system of "northern farming" for northern regions just as there is need for a system of "Dry Farming" for dry regions or one of "Humid Farming" for wet ones.

WATER THE LIMITING FACTOR IN DRY CLIMATES.

Water is generally the limiting factor in crop production here. In other words, it is the chief cause of low yields. From 250 to 1,000 pounds of moisture is extracted from the soil and transpired by the plant into the air in the process of forming one pound of dry organic matter in its tissues. In Western Canada we receive from 12 to 20 inches of water from the clouds annually. The precipitation in most agricultural countries ranges between 10 inches and 150 inches per year. Our supply is small and our need is great. Man must furnish what nature does not supply. Otherwise he must be content with low yields.

In humid regions the supply of moisture from the clouds is generally sufficient to produce large returns. In arid and semi-arid climates there is insufficient rainfall to produce large crops every year with the result that the supply of water must be increased artificially, as by irrigation, or steps must be taken to store a portion of one season's moisture in the soil for the use of the next season's crop, as by summer-fallowing, or the use of intertilled crops.

The efficient utilisation of our precipitation for the development of the latent wealth that is in our soil is the biggest material problem Western Canada has to face. She has made some progress towards its solution, but much work still remains to be done.

PLANT FOOD, THE LIMITING FACTOR ON POOR SOILS.

Of the eighty odd chemical elements known to science, fifteen may be used by plants, but only ten are essential to growth, and of these ten, all but four—nitrogen, phosphorous, potassium and calcium or lime—are provided in liberal quantity in the soil. The available supply of these essential elements of plant food is sometimes so small in humid climates and on poor soils that it makes large yields an impossibility. The result is that the maintenance of the supply of these elements is generally the chief problem of those regions, and the terms "manure" and "fertiliser" are therefore almost synonymous with soil fertility.

In Western Canada our *normal* soils are rich. The total supply of the chemical elements essential to plant growth is relatively large, so large in fact that we are permitting ourselves to neglect almost wholly the question of its conservation, yet the maintenance of this generous supply is likely ultimately to be a very serious and difficult problem. At the same time our immediate difficulty is one of developing our resources rather than conserving them. Nevertheless, it should be possible for us to do what older agricultural countries have done, viz., conserve our soil resources while still developing them. It would seem to be the part of wisdom to direct more of our energies and resources toward the solution of this difficult question.

THE IMPORTANCE OF GOOD SEED.

The seed we sow may be good or poor. Its vitality may be lessened by frost or other injury, its vigour lowered by disease and exposure and its health and purity affected by disease spores and weed seeds.

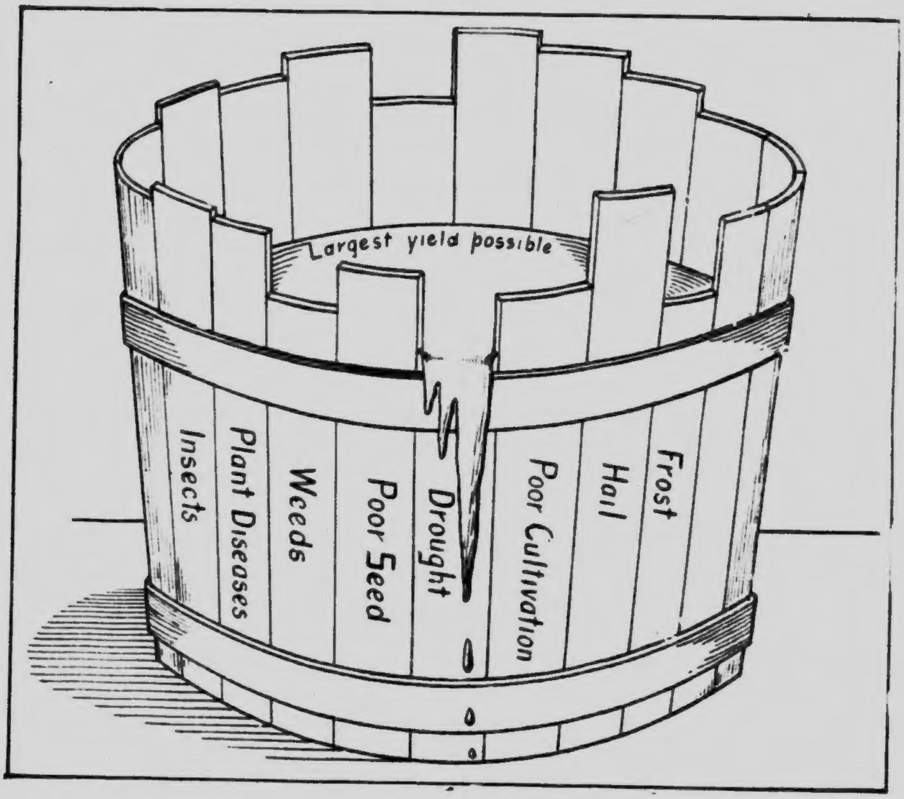
It is man's privilege to see that the seed he uses will germinate and germinate vigorously, that it is free from disease and admixture, and that it is a sort that is suited to the climate and soil where it is to be planted. These are fundamental requirements. They constitute the primary elements of successful crop growing. They are the only things essential in good seed, and fortunately for us each quality is absolutely within our power to control.

SOME FUNDAMENTAL FACTS.

These conditions are all absolutely essential to growth. When each is provided in suitable quantity and in available form, the soil produces abundantly. If any one is lacking, no growth whatever will take place. And it is important to note that the factor that is present in smallest quantity in relation to the need of the crop will determine the yield. A chain is as strong as its weakest link. The yield of a crop will be as high and no higher than the supply of the limiting factor will permit.

The Vital Part of the Problem—That of Profit

But it is not enough that man should know the factors that are essential to plant growth. The intelligent farmer does not farm for his health alone. For him there must be some profit after the various items in the cost of production have been paid.



Another Soil Fertility Barrel showing APPARENT causes of poor crops. Each farmer must determine for himself, under his own conditions, which are the chief causes of low returns, and then take such steps as are necessary to remedy them.

It is not difficult to grow crops. It is not very difficult to grow forty bushels per acre. But it is a difficult matter to grow crops at a profit—even forty bushel ones.

FACTORS AFFECTING PROFIT.

Suitable crops planted in productive soil according to up-to-date methods do not necessarily yield profitable returns. In order that a profit may be secured, not only must all the conditions of growth be provided, but first, the crop must be protected from:

1. Weeds which rob it of its plant food and moisture and increase the cost of production;

2. Insect, animal and bird pests which lesson the yield or quality of the crop either before or after maturity;

3. Plant diseases which nourish themselves on the tissue of plants and thus lessen their yield or quality or both; and

4. Severe storms which injure the soil and damage the crop by "drifting," or by stunting, lodging or breaking down the plants or by shattering the grain.

And second, *either the cost of production or the selling price must be controlled.*

THE PRICE OF WEEDS.

It has been estimated by the Department of Agriculture that the weed crop of Saskatchewan costs her farmers $25,000,000 a year, and probably this item does not cost the average farmer in Saskatchewan more than it does the average one of the other prairie provinces.

THE COST OF INSECTS.

The Dominion Department of Agriculture places the loss through destruction of crops by cutworms in one district in a single season at 35,000 acres. And the cutworm is only one of dozens of insects that take an annual toll from the farmer's crops.

THE LOSS FROM RUST.

The loss to Western Canada from rust alone in the year 1916 at the October price of $1.50 a bushel, assuming six bushels decrease on each of the approximately 10,000,000 acres under crop, reaches the enormous sum of $100,000,000. In other years wheat smut, flax wilt, potato blight and other diseases have contributed to the large annual loss from plant diseases.

THE AMOUNT HAIL TAKES FROM THE PROFITS.

The loss from hail is variously estimated at from ½ to 2½ per cent. of the total acreage, or on the basis of the 1916 crop a loss of 50,000 to 250,000 acres. In the presence of hail storms man is impotent. They come as the insurance men say "by act of providence." It is fortunate that the organisations of both private and co-operative hail insurance companies have offered provision for carrying this risk.

The damage done by hail in the year 1916 was considerably greater than the highest of these percentages.

THE MORAL.

And yet these losses occur even after the soil has been made productive. It is apparent that one of three things must result: (1) Those factors which affect cost must be controlled, or (2) the price must be regulated by the producer, or (3) the business of growing crops profitably cannot be controlled, and is therefore more or less of a gamble.

THE COST OF PRODUCTION AND THE SELLING PRICE.

Profit is measured by the difference between the cost of production and the selling price. The former is, to a considerable extent, within the farmer's power to control, but the latter is almost altogether beyond his influence.

Intelligent and timely cultural practices, hard work, good management and frugal habits will lower the unit cost and improve the unit value. But it is equally true that the cost of the farmers machinery and other equipment, the cost of his money and, to some extent, the cost of his living is fixed by conditions or institutions over which he has no control, and these are factors that enter into the cost of production.

The price a man gets for his wheat is fixed by the law of supply and demand, the tariff schedules, the cost of transportation and the machinations of middle men. Individually producers can influence the price of wheat about as much as they can the state of the weather. If the farmer is ever to get a bigger proportion of the consumer's price, it seems apparent that it must be through co-operative effort.

Increasing the acre yield of crops increases the value of the producer to the state. It may or may not increase his value to himself. Up to the point where higher yields do not increase the bushel cost, the additional return is secured at a profit. Beyond this it is not profitable to go so long as there is cheap land uncultivated.

Greater total production may or may not mean greater profit to individual producers. It generally does mean greater wealth to the state as a whole. When the supply is large, prices drop, the producer gets a smaller price and the consumer pays less. When the supply is small prices increase, the producer gets a higher price and the consumer pays more. The largest crop the United States ever produced increased the wealth of that country more than any other crop, but the farmers did not get as much money for it as, they did for each of several smaller crops which cost the consumer more, and which did not increase the national wealth of the country as much.

It is patriotic to produce large crops, either on a small or a large acreage, but it may not be good business for a farmer. It is good business to increase the acre yield to the point where the bushel or the dollar profit starts to drop, but no further, unless additional capital has accumulated and is seeking investment and is content with smaller returns. In this age of division of labour and specialisation of effort, it would seem that the goal to be aimed at by the farmer is not, as too frequently has been the case in the past, a blind effort to increase the yield, more or less disregarding profit, but rather the net profit he can make on his investment. While other classes of society measure their business success by "profits," the farmer in order to compete with them in citizenship must meet them on the same basis. The "greatest profit" rather than the "greatest production" should in fairness to himself and his family form the basis of his business plans.

The "back to the land" movement is a cry for greater production by the man who is not on the land, with a consequent lower cost to himself at the expense of lower prices to the producer. When economic factors are such as to improve the conditions on our farms, men will not have to be coaxed to go on the land, nor to stay there. Until they are improved, this old song of more than two thousand years will still be sung by those who prefer to remain in urban communities to those who are not sure where they want to be.

The price of crops in the future, as in the past, will in large measure be controlled by the law of supply and demand. But may not the supply be made more uniform? And may not a fair valuation of the services of transportation companies and middle men be determined to the satisfaction of all? That is the problem the farmer, the transportation companies, the middle men and the consumers must solve in the interest of society as a whole rather than that of any class or section of it.

The State's Third of the Problem—That of a Permanent Agriculture

The conditions that affect growth and the factors that affect profit are and will continue to be the chief considerations of the individual farmer. Yet a third set of conditions of vastly greater importance to the future of the state, viz., those that affect the permanence of our agriculture, remain to be considered.

We are hearing much today on the one hand about the "depletion" of the land, the loss of "fertility" and the "exhaustion" of plant food from the soil; and from another quarter about our soil being "the richest in the world," and about its supply of plant food being "inexhaustible."

We hear of land that after continuous cropping and no return of plant food, is producing as much as, or more than it did a generation ago, and we are led to ask ourselves "what is the truth?" "Do soils wear out?" "Can they become depleted?" "Are they being 'exhausted?'" These are questions upon our solution of which the future material success of Western Canada very largely depends.

What is fertility? In its narrowest sense it is plant food in the soil,—the chemical elements plants use in growing. In its broadest sense it is ability to produce crops, and includes (1) "available" plant food, (2) tilth, or the condition of the soil with relation to water and heat and air; (3) health or freedom of the soil from disease, and (4) purity or its relative freedom from weed seeds. In its broadest sense "fertility" means productiveness, which is synonymous neither with plant food nor with chemical content.

Soils do not become "depleted" or "exhausted" of the plant food elements they contain, although these may be seriously lessened, but the land may become depleted or exhausted of its "productiveness." Even such "depleted" soils might at any time be made productive, but they could not be made to produce a profit until such time as the pressure of population or some other economic condition increased the price of soil products. And if this should not happen, such soils would remain unproductive. In any case it is probable they would never redeem themselves. They would have to be built up by capital brought from some other source.

FACTORS THAT AFFECT PERMANENCE.

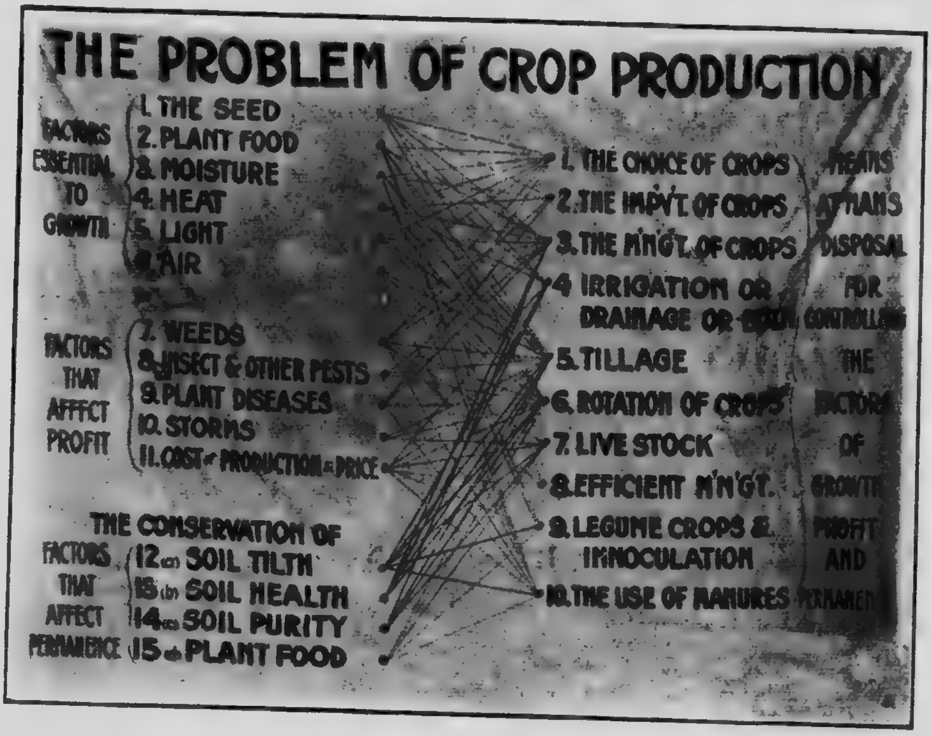
The chief factors that affect the maintenance of productiveness in any community have already been mentioned, but will bear repeating. They are:

1. The maintenance of soil tilth.
2. The maintenance of soil health.
3. The maintenance of soil purity, and
4. The maintenance of a sufficient amount of available plant food.

In addition to being productive, a permanent agriculture must also be a profitable agriculture.

And now having considered this many-sided problem the farmer has to solve, let us examine the nature and effectiveness of the instruments he has been given with which to achieve his purpose.

The means at man's disposal for controlling or influencing the factors of growth, profit and permanence.

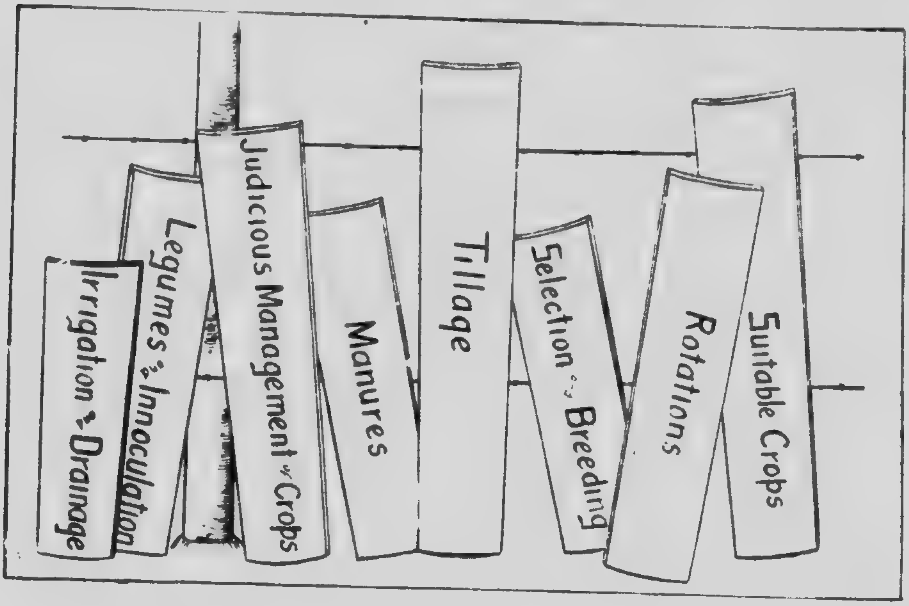


The instruments now available for controlling or influencing the factors of growth, profit and permanence are:

1. The choice of suitable crops.
2. Suitable crop management practices.
3. The improvement of crops by selection and breeding.
4. Irrigation or drainage, or both.
5. Tillage.
6. A suitable crop rotation.
7. The use of live stock.

8. The application of business principles to the management of the whole farm—the land, the stock, the labour, the machinery and other equipment, and the finances.
9. The use of legumes and nitrogen fixing bacteria.
10. The utilisation of manures.

Brief reference is all that can here be made to these, but full information concerning each is available and can be secured free of charge from any of the experimental farms or departments or colleges of agriculture.

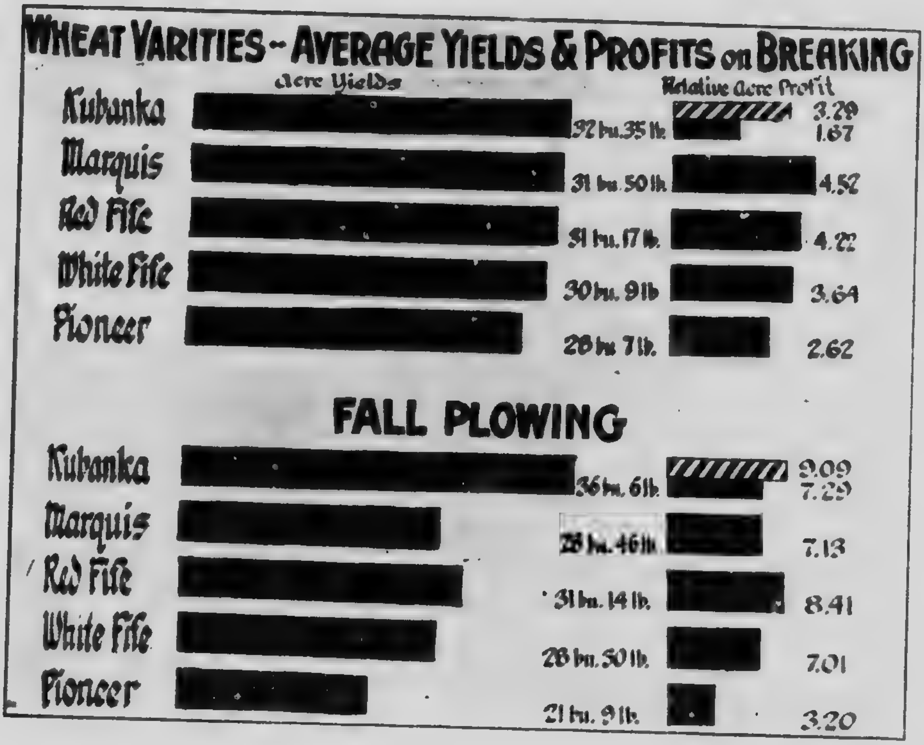


Staves that may be used to increase the capacity of the "fertility" barrel.

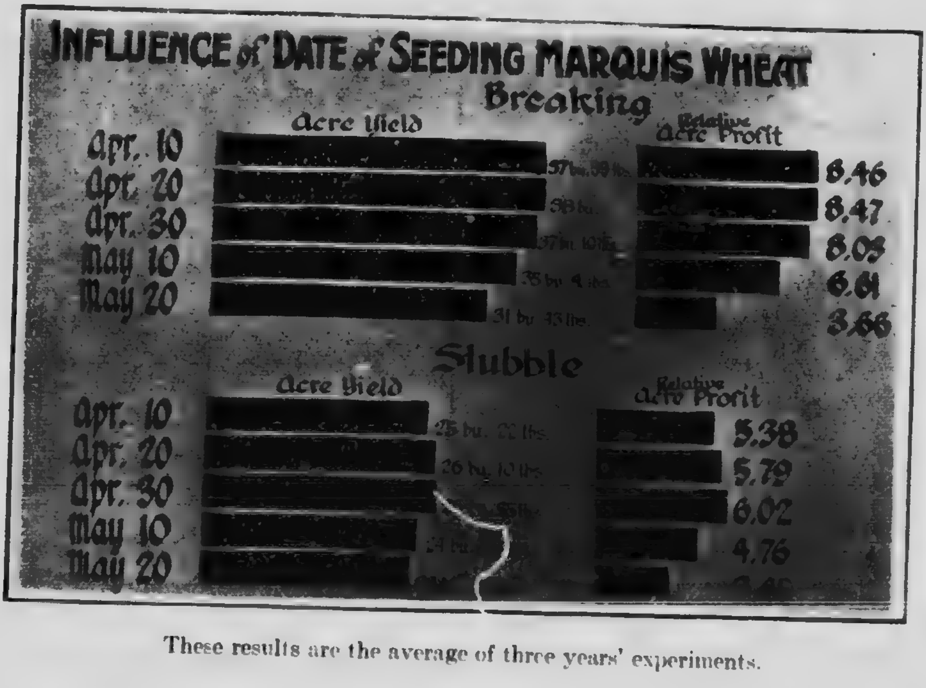
THE CHOICE OF SUITABLE CROPS.

Nature has given us some plants that resist disease, some that resist frost, some that resist drought and some that avoid these conditions. A great number of crops suited to different systems of farming are available to choose from, and the experience of farmers and the records of our experiment stations are fast teaching us the ones that are best suited to our climate and soil. The value of some new and untried crops has yet to be determined, and the suitability of different classes and types of crops for peculiar local soil and climatic conditions is a line of work that needs further investigation. But our present knowledge, if utilised, is sufficient for our present need, and we have faith that new forms will be developed or discovered that will meet any pressing requirements of the future.

Some doubts also exist concerning the relative value of different varieties for some local climatic and soil conditions, but even these are being quickly dispelled. One needs but refer to the nearest experiment station for the results of comparative tests. If these are not conclusive, co-operative trials on one's own farm can easily be made.



It is sufficient here to say that Marquis wheat, Banner oats, O.A.C. No. 21 barley, Grimm Alfalfa, Western rye grass and North-western Dent corn are recognised standard varieties in their respective classes for normal soils in the greater portion of the present settled area of Western Canada.



These results are the average of three years' experiments.

SUITABLE CROP MANAGEMENT PRACTICES.

The cleaning of the seed, its treatment for disease, the time, rate and depth of planting, and the time and method of harvesting and curing, offer many opportunities for error. In new countries, and particularly where the settlers are unfamiliar with farming, the best practices have to be learned by experience, and in the early days of such settlements this experience is often gained at a very great cost. But even now there is a considerable fund of information, sufficient at least to make a safe working guide to the successful prosecution of each of these, even under the diverse climatic conditions the different parts of the west present. The experimental farms have been given the responsibility for getting more accurate information on this subject and their results are being made available to all in their annual reports. No one need long remain in the dark concerning the "crop management" practices now recognised as suitable in different portions of Western Canada.

THE IMPROVEMENT OF CROPS.

Men are improving crops today by doing two things: (1) preventing them from deteriorating, and (2) increasing their hereditary power, with respect to yield, quality or some other economic character. The first is the business of the farmer, the responsibility for the second lies with our experiment stations.

Our crops, have in many instances sadly deteriorated by admixture with weeds and seeds of other crops, by attacks of disease, by drought and frost and by improper care of the seed. The prevention of each of these so far as possible is necessary in order to maintain productiveness and quality. It is not always within the farmers power to wholly prevent these conditions, but ordinarily he can do much to lessen their ill effects.

"Crossing" Sweet Clover on the Agricultural College Farm.

Marquis Wheat, second generation, grown under the Rules of the Canadian Seed Growers' Association, on the farm of The Agricultural Development Co., Ltd., Stranraer, Sask. Many farmers are following the methods recommended by the Association for improving the quality of their crops.

The hereditary power of our crops has been and is being improved by selection and by artificial crossing, followed by selection. It is true generally that "like produces like," but it is not always so. Variations occur in all our crops. It is necessary then that the undesirable variants be eliminated and the favourable ones isolated, tested out, and if better than the parent, increased and made available to the crop grower. This is accomplished by the selection of individual plants, the propagation of the seed in a "pure culture," the testing of its yield and constancy for a number of years, and then increasing it as quickly as possible and making it available to the crop grower.

"Crossing" is resorted to first, in order to produce variation so as to give greater opportunity for selection, and second, to engraft on a race some desirable character possessed by another. Crossing or breeding, the intermixture of the blood of two parents results in many new combinations of characters, some one of which may be the very one desired by the breeder. This favourable plant must be found, isolated, tested out, the seed increased, and then distributed. Practically all of the common crops now grown have felt the influence of the breeders' touch. Marquis wheat, Victory oats, O.A.C. No. 21 barley and No. 959 winter rye are familiar examples of improvement by selection and breeding.

IRRIGATION AND DRAINAGE.

In warm, dry climates, moisture is the limiting factor in crop production. Where water can be secured by artificial means, a profitable agriculture generally results. We practice irrigation in parts of Western Canada, but over most of our country, it is not possible to do so, because water is not available.

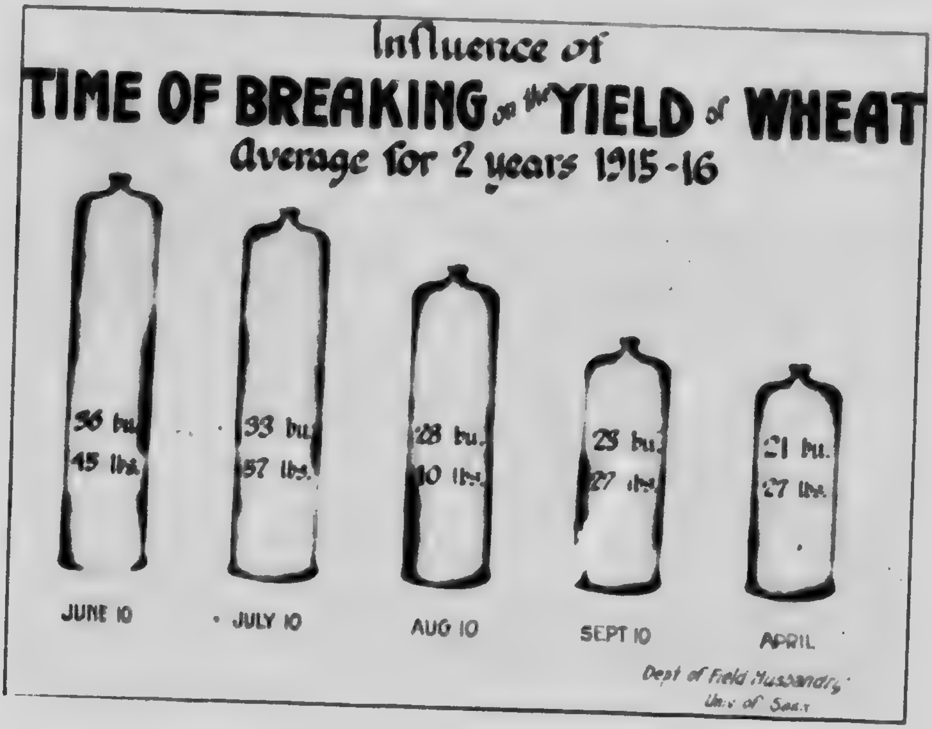
In wet climates and low lying soils moisture may also limit the yield, not because there is too little, but because there is too much in the soil. Under such conditions the removal of the surplus by artificial surface or underground drainage is just as necessary as the addition of water to dry lands. Outside a few local areas and on some low, flat lands and alkaline soils, land drainage is not a serious problem in the prairie provinces.

TILLAGE.

Tillage is the greatest means at man's disposal for controlling the conditions that at the present time are causing low yields on the farms of Western Canada. It is also by far the largest single item on the cost side of the crop account. Tillage is a universal practice, but on account of the great variation in soil, temperature and moisture, conditions in different countries and in different parts of the same country, the various methods employed are still fruitful of debate and very difficult to get light upon. At the present time in the West, tillage is the most important subject connected with crop growing, yet it is one upon which positive data concerning the relative value of different practices has reached us only during recent years, and there is much yet to be learned.

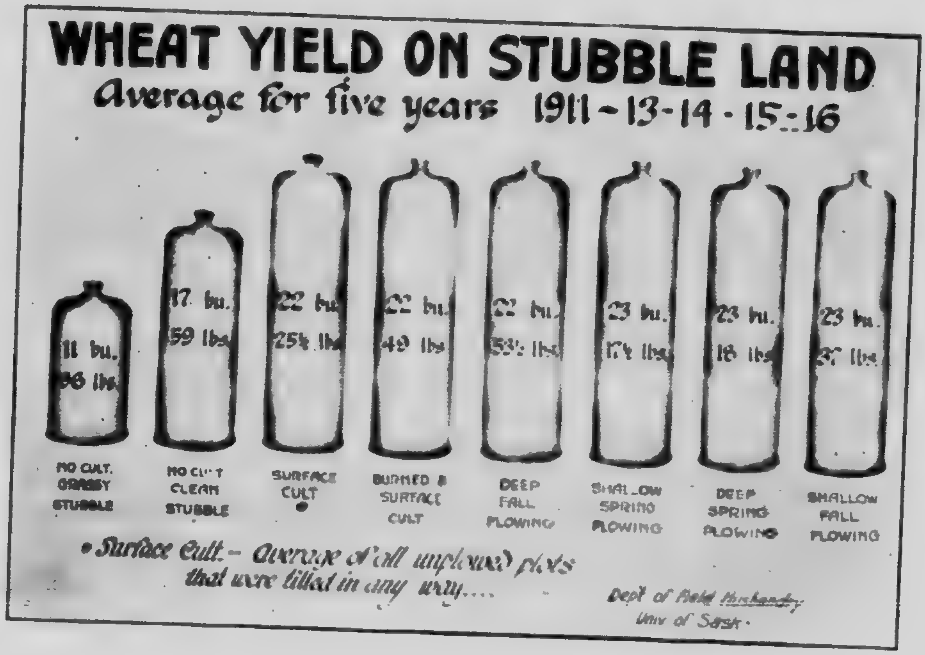
In the dry year of 1914 the yields of Marquis wheat at Saskatoon ranged from six bushels per acre to thirty-two. In the wet year of

1915 they ranged from seventeen to forty-seven. The differences were due entirely to the different tillage practices followed.



Influence of TIME OF BREAKING on the YIELD of WHEAT
Average for 2 years 1915-16

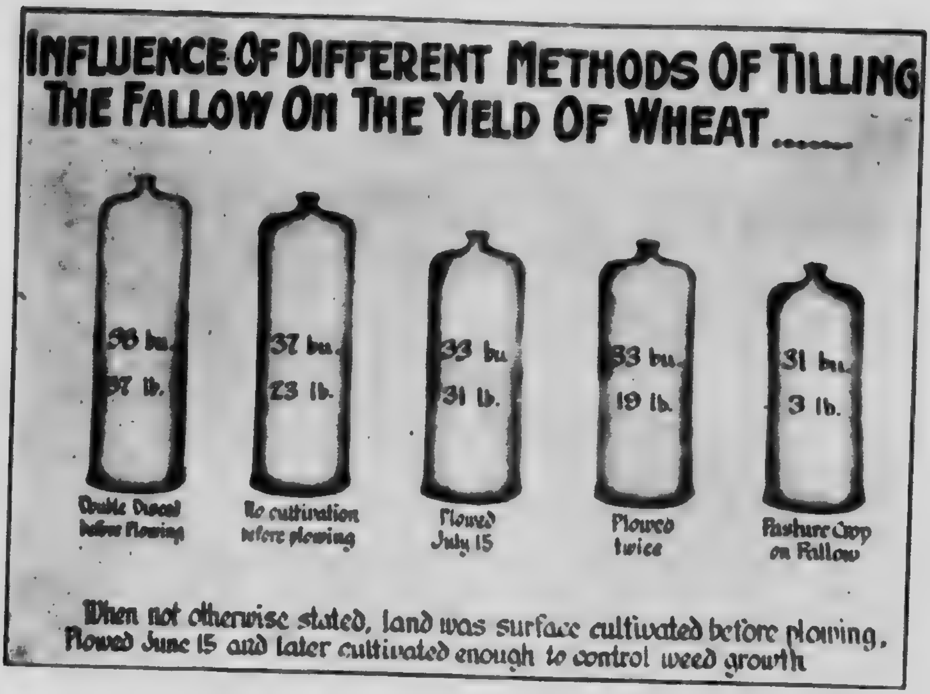
Dept of Field Husbandry
Univ of Sask



WHEAT YIELD ON STUBBLE LAND
Average for five years 1911-13-14-15-16

• Surface Cult.— Average of all unplowed plots that were tilled in any way....

Dept of Field Husbandry
Univ of Sask.



Our observations have taught us that among other things tillage may be used:

(1) To store moisture in the soil, as by deep ploughing, early in the rainy season.

(2) To conserve moisture in the soil,—as by maintaining a granular mulch on the surface by means of surface cultivation.

(3) To facilitate the movement of moisture in the soil, as by firming loose soils and loosening hard ones.

(4) To modify soil temperature,—as by lessening evaporation and by firming the soil over the seed.

(5) To increase the earliness of a crop,—as by packing, storing less moisture and developing less available plant food.

(6) To increase or decrease the air content of soils,—as by loosening hard soils and firming loose ones.

(7) To develop available plant food,—as by modifying the heat, moisture and air content of the soil.

(8) To kill native grasses and shrubs,—as by ploughing in a dry time.

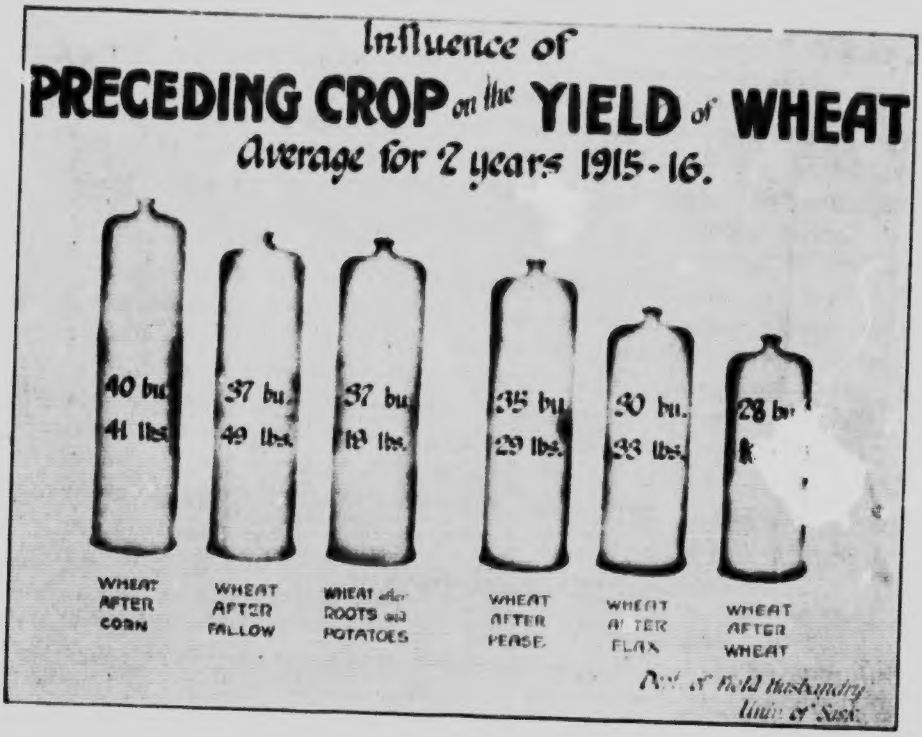
(9) To control weeds,—as by surface cultivation, to expose the roots to the sun and wind.

(10) To control soil drifting,—as by the practice of shallow ridging and the use of the granular mulch.

(11) To dispose of rubbish and cause its decay,—as by ploughing.

ROTATIONS.

The most reliable information the world affords on the value of crop rotations shows that land in England when cropped continuously to wheat for over sixty years produced an average of thirteen bushels per acre, and when grown in a rotation of turnips, barley, clover and wheat it produced 25.6 bushels per acre every fourth year for the same length of time. The most reliable information that America affords shows that corn in Illinois, when grown continuously for twenty-nine years, produced twenty-seven bushels per acre, while in a rotation of corn and oats it produced forty-six bushels, and in a rotation of corn, oats and clover, fifty-eight bushels per acre.



But we are not living in England, nor in Illinois. Their rotations do not suit the conditions found here. Yet our rotations of the future must include, as do those ones of older regions, a legume crop, an intertilled crop and a money crop. At the present time in Western Canada, legume and intertilled crops suitable for use in a large way are not available, or if so are either not well suited to all conditions or do not lend themselves satisfactorily to practicable changes in our present system of farming. Some difficulties have yet to be surmounted before paying crop rotations are discovered and firmly established.

In the meantime, the spread of weeds, the "drifting" of soil and the loss of organic matter are in many places lowering the profit from grain farming so materially that resort to hay crops occasionally is being practiced. In other places corn is coming to be a partial substitute for the fallow. It is possible that these crops, together with alfalfa, or some other legume, may be the stepping stones to a suitable crop rotation.

It has been indicated that a good rotation should include a grass or grass legume crop to aid in the control of annual and biennial weeds and an intertilled crop to help fight both annual and perennial weeds. What these crops are to be and the sequence they will follow, our farmers and our experiment stations must work out. Corn, alfalfa, Western rye grass, timothy, winter rye, beardless barley and possibly red clover, together with the cereals now commonly grown seem at present to offer the greatest promise. These are forage crops. They necessitate the use of live stock.

CROP ROTATIONS AND LIVE STOCK.

Such a change on all the farms in Western Canada will require an initial outlay of enormous capital for fencing, buildings, and stock. The greater part of this money must be made on our farms. The problem then will be solved, but slowly. Nevertheless, it will be solved. It is largely a rotation, a farm management and an economic problem. The purely agronomic or crop and soil phases of it are the least difficult to answer.

In our opinion we shall not control weeds and drifting soil permanently until we adapt our system of farming to meet those conditions which have caused and are now causing low yields and poor quality in our crops. That adaptation will include a rotation of crops designed chiefly for controlling weeds and drifting soil, for lessening the cost of production and for building up a more permanent agriculture. It will necessarily include live stock to make use of the forage crops that must be grown, and to lessen the amount, and thereby the cost of the tillage necessary to control weeds.

BUSINESS FARMING.

It is not long since the farmer did not need to be a business man. He produced his own food, he grew and manufactured his own clothing and built his own house. He lived unto himself largely. He needed little business training.

The modern farmer cannot live unto himself. He does not produce his own clothing nor the material to build his home, nor does he grind his own wheat into flour. Today he must spend, even for the necessities of life. Therefore he must have something to sell. In other words, the modern farmer must be a business man.

It does not take long to learn the art of farming, but unfortunately it takes some of us a long time to learn the art of successful farm business. It would seem that we as individuals might with profit give more attention to mathematics in relation to our business. Our profits are determined by the difference between our receipts and our expenditures, and not by our gross incomes. Let us know, if possible, the essentials of our own business enterprises. It would seem also that we as a class must practice greater co-operation. Our Grain Growers' Association and related co-operative enterprises have accomplished much in the interest of the farmer, chiefly in the marketing end of his business, and they have still much opportunity for service. At the same time let us not forget that we as individuals can still do much to lower the cost of production and to lessen the risk in farming; and both of these things are directly related to profit.

LEGUMES AND INOCULATION.

The air over every acre of land contains seventy million pounds of nitrogen, the most costly of fertilising elements. This amount is sufficient to supply the nitrogen of fifty bushel crops of wheat every year for a million years, yet farmers in some places are paying fifteen cents a pound for nitrogen to put on the land. Nitrogen in the air can be secured at no cost to the farmer if he will but grow some legume crop at intervals. These, when inoculated with nitrogen fixing bacteria, have the power of drawing upon this immense store of nitrogen in the air.

In such of our virgin soils as are rich in nitrogen it is possible that the use of legume crops may not now result in large increases in yield. Investigations at present under way will soon answer that question. In the meantime the fundamental fact regarding legumes should not be forgotten. Neither should it be forgotten that all our soils are not virgin, nor are all rich in nitrogen.

THE USE OF MANURES.

Land cropped continuously to wheat for over sixty years in England produced an average yield of 13 bushels per acre, while adjoining land cropped continuously to wheat for the same length of time, but manured heavily gave an average of 34.6 bushels.

In Illinois, as was stated previously, land continuously cropped to corn for twenty-nine years produced an average of 27 bushels per acre, in a rotation of corn and oats, 46; and in a rotation of corn, oats and clover, 58 bushels per acre. In the latter rotation when manured the yield was 81 bushels, and when manured and fertilised the average yield was 96 bushels of threshed corn per acre.

At the present time we cannot get such large increases from the use of either manures or commercial fertilisers, although we can and do get paying returns from the use of manure, even on our new soils.

In this connection a definite statement regarding the amount of the more important plant food elements in Western soils and the actual results of the application of manures and fertilisers to them may not be out of place.

In the surface 6 2-3 inches of the normal Saskatchewan soils so far analysed by the department of chemistry of the University of Saskatchewan, the nitrogen supply ranges from 3,000 to 14,000 pounds, the phosphorous from 1,000 to 3,000 pounds, and the potassium supply from 14,000 to 45,000 pounds.

Assuming that the straw were all returned to the land, the amount of these elements removed from the soil in the production of one bushel of wheat would be 1 2-5 pounds of nitrogen, 1-5 pound of phosphorous and about 1-5 of a pound of potassium.

It is, therefore, apparent that if all of this plant food could be utilised by crops without loss, there is enough nitrogen to produce from 2,000 to 10,000 bushels of wheat, enough phosphorous to produce 5,000 to 15,000 bushels and enough potassium to produce from 70,000 to 225,000 bushels in the surface 6 2-3 inches of one acre.

Man would take out all this wheat in a year if he could, and leave none for future generations, but providence has wisely provided that only about 2 per cent. of certain elements, 1 per cent. of others and 1-4 of 1 per cent. of still others can be annually released from the soil and taken up by growing plants, so that we cannot *deplete* our soils of their *potential* wealth if we would, any more than a frog can reach the opposite end of a log by jumping once each year one-fiftieth of the remaining distance, but we can and are depleting even the best of our soils of their surplus wealth and their productiveness. We must not let the supply of total plant food get so low that the small percentage that becomes available to plants annually will be insufficient for a large crop.

It may be asked, why add manure or other fertiliser to soil containing so much plant food? The answer is to be found in the proportion that is available to plants. The elements added in decayed manure are quickly available to the plant, while much of that found in the soil is not. And in addition, decaying organic manures not only improve the physical conditions of the soil, lessen its tendency to blow, and improve its moisture holding power, but also liberate or make available other more or less insoluble plant food elements.

The use of manure at Saskatoon has increased the yield of every crop, even on rich land. It increased the yield of wheat six bushels, the yield of alfalfa 200 pounds, the yield of potatoes 33 bushels, the yield of roots 1,800 pounds, and the yield of corn 4,000 pounds in 1915, and in 1916 equally large increases were secured.

If a system of permanent agriculture is to be established on our Western prairies, and our future welfare depends upon its establishment, we must not carry our wheat system too far. We cannot waste the fertility of our soil and still have it. Today we are selling our soil fertility at the rate of 25 cents per bushel of wheat. We individually can afford to do that for some time, but the state cannot afford to permit us to do it indefinitely.

IN CONCLUSION.

Tillage, the choice of suitable crops and suitable cultural practices will enable us to develop the resources of our soil. Business methods and in some places a rotation of crops and the introduction of live stock will enable us to produce crops more profitably, but only the use of legume crops, the practice of a crop rotation and the return to the soil of some of the plant food we remove in crops and in fallowing will enable us to build up a permanent agriculture, and a permanent agriculture is absolutely essential to the future well-being of the state.

In the final analysis our ultimate success as a nation depends not only upon our ability to produce profitable crops now, but upon our ability to keep on producing profitable crops.